



COMMONWEALTH OF KENTUCKY
DEPARTMENT OF HIGHWAYS
FRANKFORT

HENRY WARD
COMMISSIONER OF HIGHWAYS

March 13, 1961

ADDRESS REPLY TO
DEPARTMENT OF HIGHWAYS
MATERIALS RESEARCH LABORATORY
132 GRAHAM AVENUE
LEXINGTON 29, KENTUCKY

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MEMO TO: D. V. Terrell
Director of Research

The attached "Performance Report on Bridge Resurfacings with Silica Sand-Asphalt Mixture" by Robert L. Florence, describes the condition of two bridges surfaced in 1958. The construction report for this project was prepared by L. H. Strunk as "Memorandum Report on Bridge Resurfacing with Silica Sand-Asphalt Mixture", and dated December, 1958.

During the first year of service and up until late January, 1960, the Clark Memorial Bridge in Louisville showed a minimum number of places requiring any maintenance. A series of freeze-and-thaw cycles with snow and then water on the bridge in February and March, 1960, caused a number of failures in the concrete deck of the bridge. In most of these failures, the concrete deck spalled and came off at a depth just above the reinforcing steel in the deck slab (Note Fig, 8, following page 6). The failed locations were cleaned and patched in the early spring of 1960.

Following the snows and the freeze-and-thaw cycles of the past December, January and February, additional sections of the concrete deck have popped off and required extreme patching.

The original tack coat and sand-asphalt surface did not prevent water passing through into the concrete. A heavy tack coat and richer mixture could probably have prevented some of the water from getting into the deteriorated concrete.

March 13, 1961

It appears that some considerable portions of the concrete deck will eventually have to be removed and replaced. It is hoped, however, that this work can be deferred through maintenance until construction has been completed and one or more of the new bridges can be opened to traffic. Recommendations for repairs and maintenance are being prepared, and they will be submitted separately.

Respectfully submitted,



W. B. Drake

Associate Director of Research

WBD:d1

Att.:

cc: Research Committee Members
Bureau of Public Roads (3)

Commonwealth of Kentucky
Department of Highways

PERFORMANCE REPORT

on

BRIDGE RESURFACINGS WITH
SILICA SAND-ASPHALT MIXTURE

by

Robert L. Florence
Research Engineer Associate

Highway Materials Research Laboratory
Lexington, Kentucky

March, 1961

INTRODUCTION

When the Maintenance Division found it necessary to resurface the Clark Memorial and Ashland-Coal Grove Bridges in 1958, a thin, silica sand-asphalt, wearing surface was recommended by the Research Division. The basis of the recommendations was the promising results obtained in laboratory testing and the apparently successful resurfacing of bridges with thin applications of silica sand-asphalt in the New York Area (1) and elsewhere. The design and construction details pertaining to these two projects have been reported previously (2)(3). This report is a record of the performance of the two projects and of the repair of spalled areas on the deck of Clark Memorial Bridge.

CLARK MEMORIAL BRIDGE

The Clark Memorial Bridge was resurfaced with an approximate thickness of 0.4 inch of silica sand-asphalt in October, 1958. The project cost approximately 61 cents per square yard, which included

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- (1) Ruefer, A. L., "Test Installations of Silica Sand Resurfacing," Bulletin 188, Highway Research Board, 1958.
 - (2) Strunk, L. H., "Memorandum Report on Bridge Resurfacing with Silica Sand-Asphalt Mixture," an intra-departmental report, Highway Research Laboratory, Kentucky Department of Highways, Lexington, 1958.
 - (3) Florence, R. L., "The Design of Thin, Silica Sand-Asphalt Wearing Surfaces for Highways and Bridges," an intra-departmental report, Highway Research Laboratory, Ky. Dept. of Highways, 1959.

the cost of cleaning and patching the existing surface. The traffic count at the time of surfacing was approximately 45,000 vpd. Since the surfacing was laid, three detailed inspections have been made. A strip map showing the general location and types of failures which occurred prior to February, 1960, is included in the Appendix.

The first inspection was made March 25, 1959, five months after the sand-asphalt surface was laid. Approximately 35 small potholes, extending through the sand-asphalt and into the concrete deck, developed during the first winter. Most of the potholes had been cold-patched by Maintenance. The potholes and hairline cracking developed primarily on the approach ramps and along the gutter of the outside, north-bound lane. It was reported after this first inspection that the areas of surface showing cracking corresponded closely to those areas showing most severe damage from salt prior to resurfacing. The pothole shown in Fig. 1 was photographed at the time of the first inspection. The sand-asphalt surface was worn through in two areas on the Louisville approach ramp where the material had been hand placed and was very thin.

The second inspection was made on February 3, 1960, just prior to a period of severe winter weather. Hairline cracking was more extensive, but only a few new potholes had opened since the first inspection the previous year. Some peeling off of the sand-asphalt on the lateral steel joints was noted. Marks left on the surface by the paver

screed had worn smooth under traffic. A few small scalled areas were noted which were apparently due to inadequate tack coverage. There was evidence that the deep patches on the south-bound lanes of the Louisville approach ramp had shoved, as shown in Fig. 2. The worn areas were somewhat larger than they were at the time of the previous inspection.

The third inspection was made March 21, 1960, just following the period of freeze-thaw, mentioned above; and almost every area that had been noted as "cracking", less than two months earlier had developed into potholes. A large number of them extended down to a depth of approximately 1-1/2 inches to the top reinforcing steel. Loose material from the potholes had collected in the gutters. Moisture was evident under the cracked material when it was pulled up by hand. It was noted on this inspection that white spots, which appeared to be salt, visible on the underside of the deck corresponded to the locations of potholes on the surface above. Damage to the deck was most widespread and severe on the approach ramps, shown in Fig. 4. Within the truss-spans of the bridge, the damage was primarily in the gutterlines and along construction joints. The most extensively damaged area on the truss-spans was along the gutter of the north-bound lanes.

Roughness developed to such a degree that it was hazardous to the traffic on the bridge, and it was necessary to patch the surface

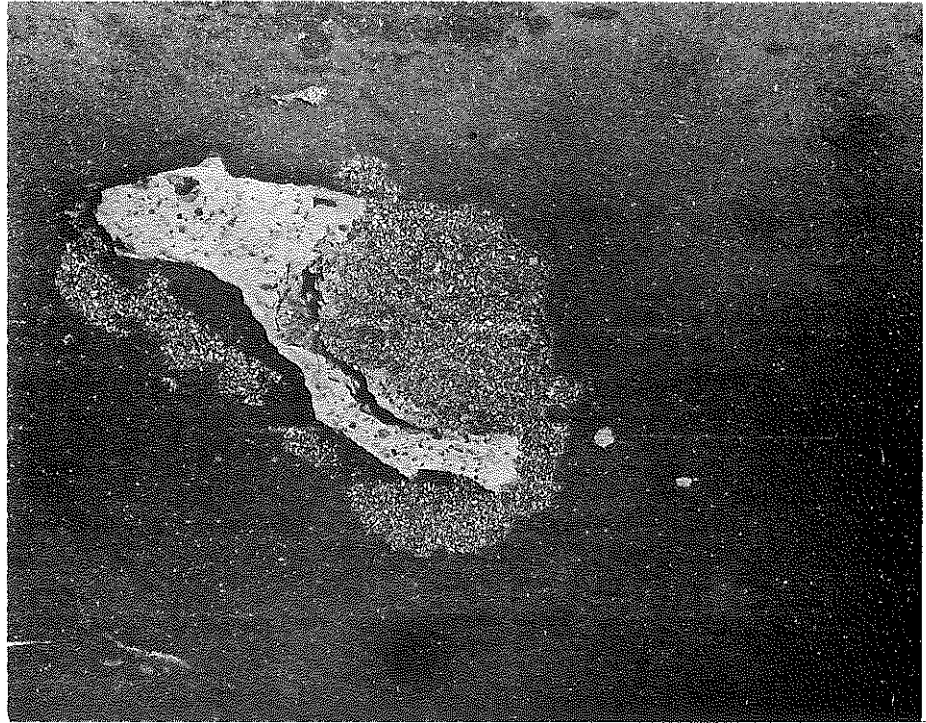


Fig. 1. A Deep Pothole which Developed During the First Winter.



Fig. 2. Shoving, in the Deeper Patches, Became Apparent Within a Year After Re-Surfacing on the Louisville Approach Ramp. South-bound traffic brakes to a stop on the grade.



Fig. 3. Sidewalk Indiana Approach Ramp. This section of sidewalk had to be removed and bridged over with planks since this photograph was taken.



Fig. 4. The Approach Ramps Sustained the Most Severe Damage.

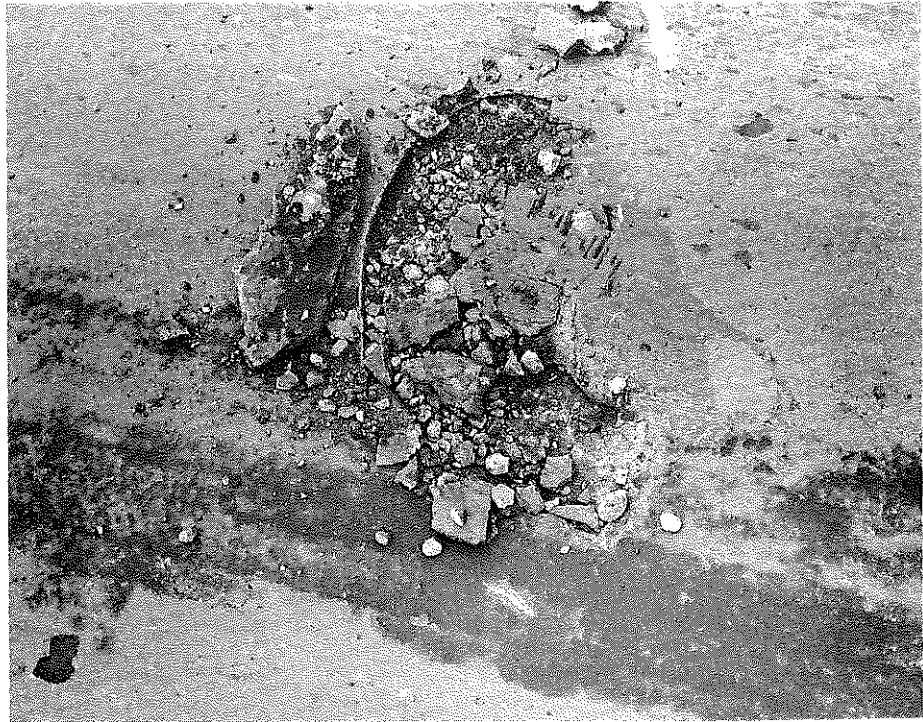


Fig. 5. Areas which Appeared as Fine Cracking Revealed Spalled Concrete Underneath When Broken Open.



Fig. 6. Example of Damaged Concrete. Depth of damage was approximately 1-1/2 inches in most holes. Damage at construction joints extended much deeper.

at the very earliest opportunity. Repair work began March 22, 1960, on the north-bound lanes of the Louisville approach ramp. The maintenance crew used pneumatic hammers to loosen the damaged concrete, and the holes were swept clean by using a jet of compressed air. The sand-asphalt was chipped away several inches back from the edge of the spalled area and squared. It was noted that the original sand-asphalt still adhered to much of the damaged concrete cleaned from the cracked areas.

It was planned initially to use the Kentucky (natural sandstone) Rock Asphalt, which Maintenance had stockpiled, and to use heated SS-1 as the tack. The natural rock-asphalt was to be dry heated to drive off moisture and cure the natural asphalt. However, at the start of the repair work, it was found that the George Eady Company was making plant-mix for the City of Louisville and that the material in his fines bin would make a satisfactory sand-asphalt mixture. It was agreed then to substitute the preferred plant-mix material for natural rock asphalt. Arrangements were made for a mixture of the following proportions:

Aggregate: 33% fine bank sand
67% medium river sand

Asphalt (PAC-3): 9%

A sieve analysis of the sand combination was as follows:

<u>Sieve No.</u>	<u>Percent Passing</u>
8	100.0
16	98.8
50 ,.....	43.5
80	24.8
100	20.1
200	11.3

This grading is similar to that of natural rock-asphalt sand except it has much more filler-size material. The asphalt cement (PAC-3), for the patching mixture, was the same grade as used in the original sand-asphalt surface. The mixture was to be supplied at intervals, and in quantities as needed. The mixture was supplied at a price of \$6.55 per ton.

Holes were tacked by hand-painting heated SS-1 over the entire failed area, and the tack was applied far enough ahead to allow the emulsion ample time to break before the patching mixture was placed. The patching material was placed in the holes and raked. The loose material was heaped higher -- according to the depth of the hole -- than the existing surface. This was an attempt, of course, to obtain a smooth patch having uniform density after compaction. Several holes on the Louisville approach ramp were patched with steam heated, natural rock-asphalt more-or-less on a trial basis. The natural material was very unstable, and traffic abraided it and routed it from the patched areas shortly after it was placed.

The first few patches were compacted with a vibratory compactor; however, the compactor tended to bounce out of control when operating against the solid concrete surrounding the hole. From this standpoint, it was not suitable for compacting thin patches or for compacting the margin between the patch and the surrounding surface. A small tandem roller gave better compaction; but, because of its small wheels, it could not be used to roll patches close to the curb. A larger roller was then brought on the job to roll these patches and for the final rolling.

Due to heavy traffic on the bridge, work was done between 9:00 a.m. and 3:00 p.m. in order to avoid the peak traffic hours, and only one lane was worked at a time. After the first two days, two crews were working; one crew cleaned the holes ahead of the patching crew. Actually, the cleaning crew worked several nights and one full day in order to permit the tacking crew to work far enough ahead to allow the heated emulsion to cure before the patching mixture was placed.

The traffic island on the Louisville approach ramp was torn out and reconstructed with the sand-asphalt patching mixture. Some thin spots in the original sand-asphalt surface on the Louisville approach ramp were also patched -- although there were no failures in the concrete in these areas. The patching was completed April 6, 1960.

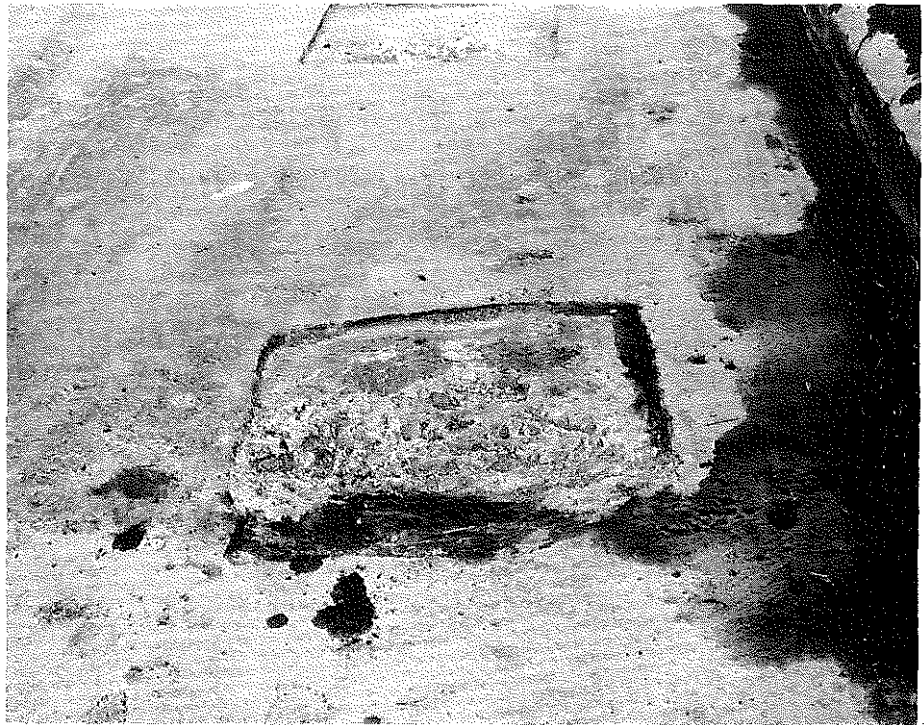


Fig. 7. Edges of the Cleaned Holes Were Cut Square to Achieve a Good Joining of the Patch and the Surrounding Surface.

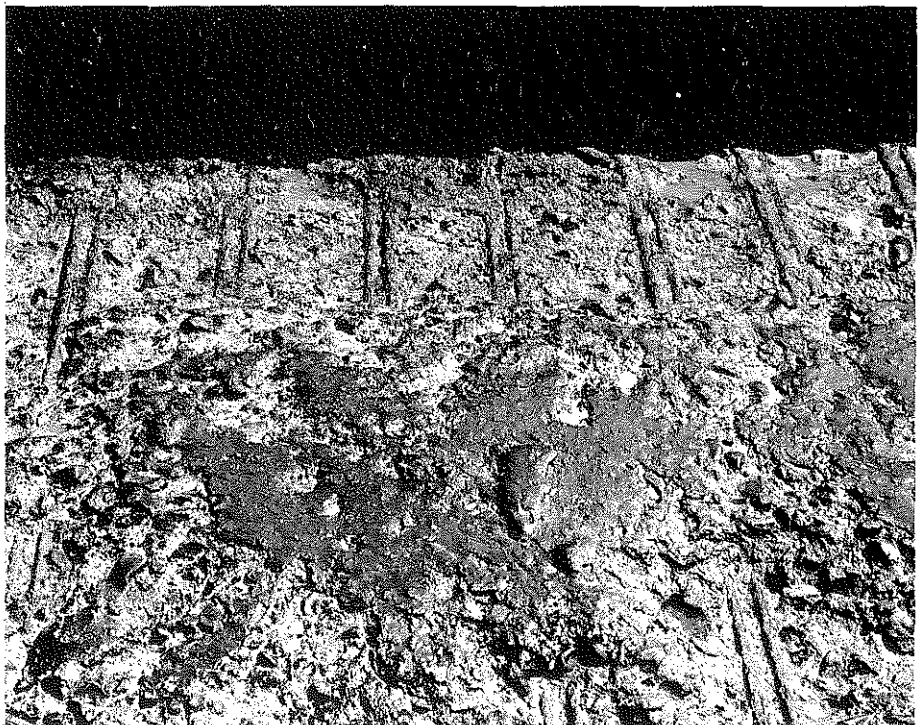


Fig. 8. Heated SS-1 (Emulsion), Painted in the Cleaned Holes, Broke Rapidly and Gave Complete Coverage.



Fig. 9. The Patching Mixture Could be Worked Easily by Hand at Low Temperatures.

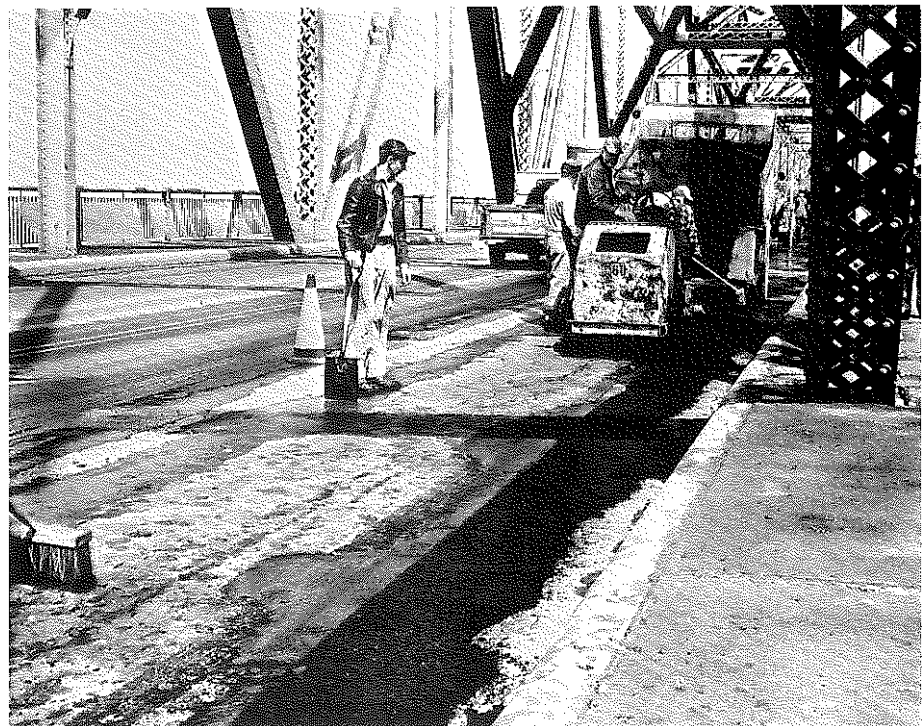


Fig. 10. A Small Roller Gave Better Compaction Than a Vibrating Compactor Due to the Shallow Patches and Resilience of the Bridge Deck.

LABORATORY INVESTIGATION

A sample of the patching mixture was tested in the laboratory by the Marshall method, and the asphalt content and gradation were determined. The following average values were found:

Marshall Stability (lbs.).....	955
Flow (0.01 in.)	8.8
Unit Wt. (lb/cu.ft.)	129.8
Percent Air Voids	10.6
Asphalt Cont.: by extrac. (%)..	9.1

Gradation

<u>Sieve No.</u>	<u>Percent Passing</u>
4	100.0
8	96.1
16	92.8
30	71.7
50	35.3
100	17.3
200	6.8

Samples of the original sand-asphalt surface taken from the failed areas were tested in the laboratory for density, permeability, asphalt content, and gradation. Samples taken from various points on the outside north-bound lanes gave the following average values:

Unit Wt. (wt. in air & water).....	140.8 lb/cu.ft.
Unit Wt. (by mercury displacement)	139.7 lb/cu.ft.
Asphalt Cont. (by extraction).....	9.9 %
Air Voids, %	2.5 %

Gradation

<u>Sieve No.</u>	<u>Percent Passing</u>
4	100.0
8	99.8
16	98.1
30	84.9
50	55.4
100	32.5
200	18.4

Surface samples taken from the outside, south-bound lanes gave the following average values:

Unit Wt. (by mercury displacement) ... 134.0 lb/cu.ft.
Asphalt Content 9.8 percent
Air Voids, % 7.5

Gradation

<u>Sieve No.</u>	<u>Percent Passing</u>
8	100.0
16	97.8
50	50.2
100	25.9
200	14.7

The densities of the original surface were higher than that initially predicted by the Marshall method. The average percent air voids for which the mixture was designed, was calculated to be 10.2 percent. Of course, the asphalt contents of the sample taken from the deck include whatever quantity of asphalt was also used in the tack. The low percentage of voids (2.5%) in the surface of the north-bound lanes, emphasizes

the importance of designing for a void content of at least 10 percent (by Marshall compaction) in the mixture in order to allow for the absorption of any excess tack when the material is placed in such thin layers. The high density is also largely explained by the excess filler-size aggregate in the sample taken from the north-bound lanes.

Samples of the original surface material were re-heated and compacted into specimens 2 inches in diameter and 4 inches high and to a density of 137.5 lb/cu.ft. (4.7 percent voids); these were tested in a soils permeability apparatus; and, the average coefficient of permeability was 1.9×10^{-6} cm./sec. This value compares favorably with values measured in the laboratory for Class I, Type B surface.

Swiss rebound hammer readings were taken at several places on the bridge deck. Readings taken on the concrete adjacent to many spalled areas indicated that the concrete was not sound even though it appeared solid upon visual inspection.

ASHLAND-COAL GROVE BRIDGE

The Ashland bridge also had a concrete deck which had previously been resurfaced with Class I bituminous concrete containing slag aggregates, but the existing surface had been patched and worn slick. The sand-asphalt surfacing, 0.4 inch, was laid on the bridge September 14, 1958. No patching was done with the sand-asphalt mixture, although some earlier maintenance patching had been done.

The first inspection was made February 22, 1960, one year and three months after the sand-asphalt was laid. At that time, no cracking was noted; and the only failures were ten small holes extending through the sand-asphalt and the 1-1/2 inches of asphaltic concrete to the original bridge deck. On the Ohio approach, the sand-asphalt was worn through in a turning area where the material was very thinly laid. There were tire chain scars on the Ashland approach ramp. The over-all appearance at that time was very good.

The second inspection was made March 18, 1960, just prior to the last inspection of Clark Memorial Bridge. No new holes had developed, although the sand-asphalt had peeled off of a transverse, steel joint. . There were also large areas of fine cracking -- primarily in the outside wheel tracks. In two small areas, the sand-asphalt had peeled off the underlying asphaltic concrete. Tire-chain scars were much more extensive than on the previous inspection. Of course, it is obvious from this that icy winter weather intervened between the two inspections. Some of the chain scars were through the sand-asphalt course and extended into the asphaltic concrete. No evidence of pushing, or bleeding was found on either inspection. A strip map, showing the location and types of failures noted on this inspection, is included in the Appendix.



Fig. 11. Ashland-Coal Grove Bridge, Photograph Showing Tire Chain Scars on the Ashland Approach Ramp.



Fig. 12. Ashland-Coal Grove Bridge, Showing Typical Appearance of Cracking in the Outside Wheel-Track, March, 1960. Cracking was not apparent before the snows of February and March, 1960.

SUMMARY AND DISCUSSION

It was noted in the memorandum report by L. H. Strunk on the resurfacing of the deck of Clark Memorial Bridge (2) that the approach ramps and the outside, north-bound lane were the areas in which the most extensive damage to the concrete in the deck had occurred. Large areas on the approach ramps were cleaned down to the top steel. At the time of the first inspection, 5 months after resurfacing, and following the first winter, cracking and holes began to show up in these same areas. This was further borne out on the second inspection. The relatively severe damage to the outside north-bound lane is probably due to snow, ice, and moisture lingering longer on this lane -- due to northerly exposure and shading from the sun.

The performance of the sand-asphalt surface on the Ashland-Coal Grove Bridge and on sound concrete on the Clark Memorial Bridge indicates the material is capable of providing an excellent, low-cost, skid-resistant surface. The use of the material in thin layers makes it unnecessary to raise expansion joints, and this alone greatly reduces the total cost of resurfacing. It also minimizes the dead weight added to the bridge.

The cost of the initial sand-asphalt surface on the Clark Memorial Bridge was approximately 61 cents per square yard, including the cost of tedious cleaning and patching prior to the surfacing. The silica

sand-asphalt has shown excellent adherence to the existing surfaces and has worn well under very heavy traffic. Construction and installation involved a minimum of time and traffic interference. The paver-laid surfaces have not shoved or rutted under heavy traffic conditions (braking). Some shoving and bleeding has occurred in the deeply patched areas and this is attributable to the depth of the patches and the generous amounts of tack material used there. No scaling, such as has been experienced with natural rock asphalt, has occurred. However, since rock asphalt has fallen into disuse, a need has arisen in the Department's specifications for a sand-asphalt type material which can be used reliably. The performance of the bridge resurfacings and the experience of other agencies indicates the fine, silica, sand-asphalts have considerable merit in this respect as well as in more general types of resurfacings.

The purpose of the sand-asphalt surface, at least on the Clark Memorial Bridge, was to seal and protect the existing concrete deck from further deterioration. Obviously, this was not altogether successful inasmuch as extensive damage occurred during the second and third winters. However, this should not necessarily reflect unfavorably upon the sand-asphalt. It was known beforehand that the sand-asphalt mix would have a fairly high percentage of voids because it was intentionally designed so in the interest of skid-resistance and as a precaution against bleeding. The sand-asphalt course itself was very thin and somewhat

permeable. The sealing of the underlying concrete was thus entrusted wholly to the "tack" or "prime" coat.

The concrete deck was polished and oily in the same areas; and, in order to prevent the sand-asphalt from slipping, it seemed advisable to use a hard asphalt as the "tack". Also, in order to gain uniform coverage and adherence to the cold concrete, it was decided to cut-back a PAC-3. The tack was applied with the hand-spray, on the distributor, but the application was "stringy" rather than atomized; consequently, the degree of uniform coverage and penetration originally sought were not achieved. Trucks were used to track and spread the "tack" material more evenly; and, whereas this method of operation was apparently successful in gluing the sand-asphalt to the concrete and in preventing any slipping, it appears now that the "tack" was ineffective in sealing the concrete.

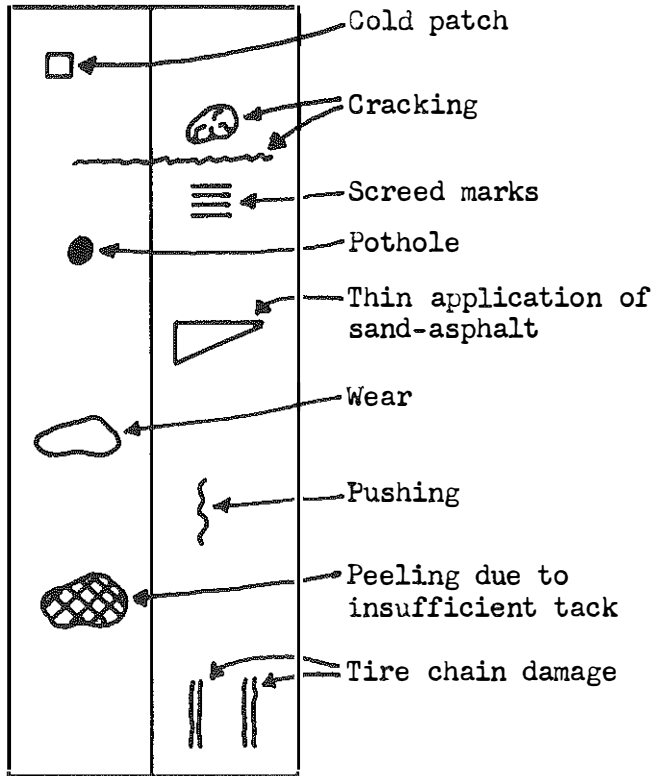
As a further observation, it appears that any unsoundness in the underlying concrete which was not discovered and removed prior to surfacing with sand-asphalt and which subsequently exhibited any movement or deflection caused the overlying sand-asphalt to crack. In fact, it is likely that the sand-asphalt aggravated the spalling in some of these areas -- by allowing water to intrude through cracks and by delaying evaporation.

In any case, the problem of sealing the concrete decks needs further attention. The cut-back PAC-3 was not sufficiently fluid to

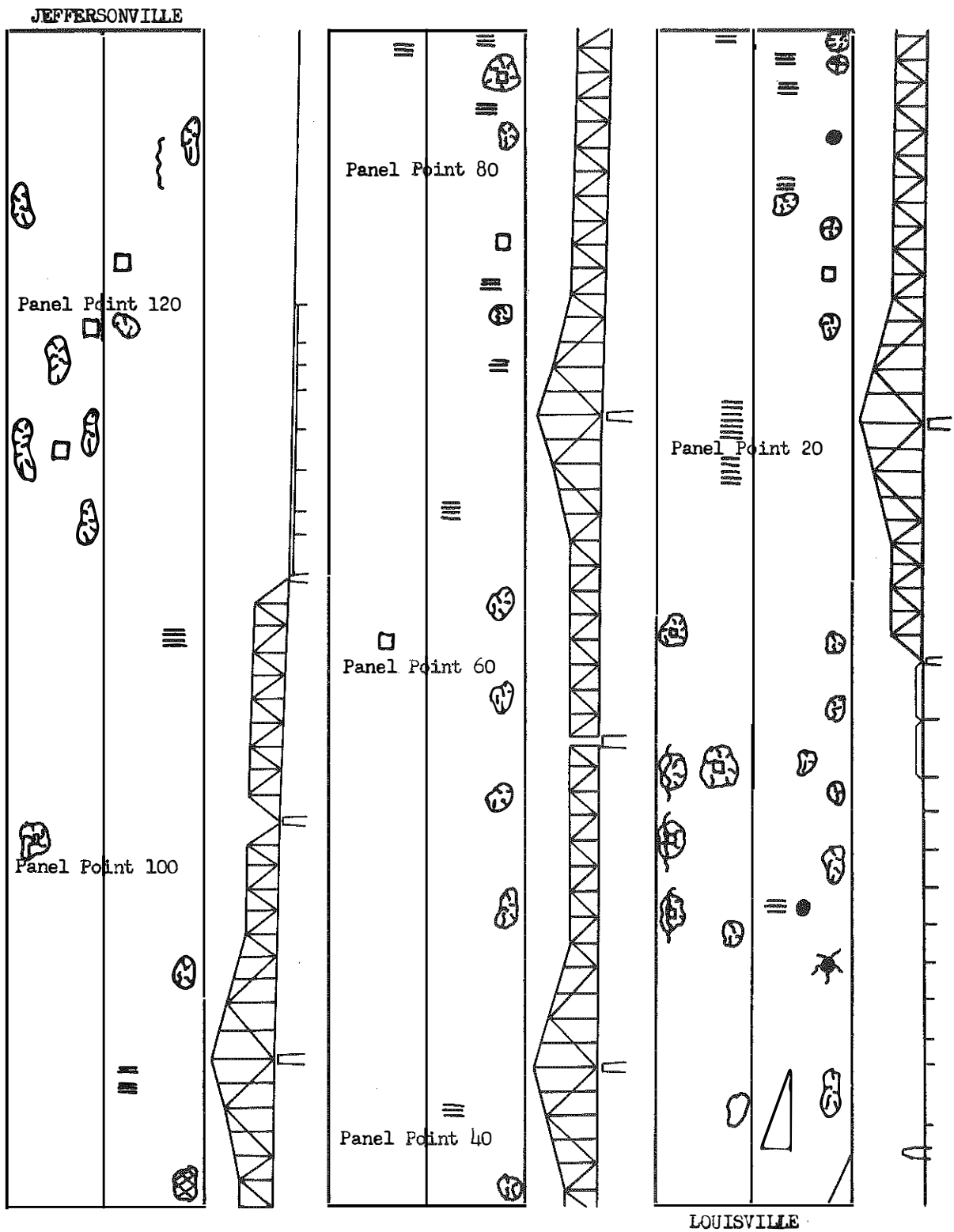
accomplish this; therefore, consideration is being directed to emulsions, such as SS-IH, which are highly dilutable and which contain relatively hard, base asphalts. This type of material would permit a generous application of liquid and allow it to soak and penetrate without undue risk of applying excesses of asphalt. Non-bituminous sealers, such as styrenes, epoxies, etc., are also being considered for this purpose.

APPENDIX

LEGEND



CLARK MEMORIAL BRIDGE
February 3, 1960



ASHLAND-COAL GROVE BRIDGE

